CHAPTER 2

Air Quality Trends

EPA has established National Ambient Air Quality Standards (NAAQS) for six criteria pollutants to protect public health and welfare. These six pollutants are carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter whose aerodynamic size is less than or equal to 10 microns (PM-10), and sulfur dioxide (SO_2). Table 2-1 lists the NAAQS for each pollutant in terms of the level of the standard, the associated averaging time, and the form of the statistic used to evaluate compliance. There are primary standards for all of the criteria pollutants. Some pollutants (PM-10 and SO_2) have primary standards for both long-term (annual average) and short-term (24 hours or less) averaging times. Short-term standards are established to protect people from any adverse health effects associated with acute exposure to air pollution, while long-term standards are established to protect the population from any adverse health effects associated with chronic exposure to air pollution. The secondary standard, which protects public welfare (vegetation, materials, and visibility), is the same as the primary standard for most pollutants, with the exception of SO_2.

Table 2-1. *NAAQS in Effect in 1995*

Pollutant	Primary (Health Related)		Secondary (Welfare Related)	
	Type of Average	Standard Level Concentration[a]	Type of Average	Standard Level Concentration
CO	8-hour[b]	9 ppm (10 µg/m³)	No Secondary Standard	
	1-hour[b]	35 ppm (40 µg/m³)	No Secondary Standard	
Pb	Maximum Quarterly Average	1.5 µg/m³	Same as Primary Standard	
NO_2	Annual Arithmetic Mean	0.053 ppm (100 µg/m³)	Same as Primary Standard	
O_3	Maximum Daily 1-hour Average[c]	0.12 ppm (235 µg/m³)	Same as Primary Standard	
PM-10	Annual Arithmetic Mean[d]	50 µg/m³	Same as Primary Standard	
	24-hour[d]	150 µg/m³	Same as Primary Standard	
SO_2	Annual Arithmetic Mean	0.030 ppm (80 µg/m³)	3-hour[b]	0.50 ppm (1300 µg/m³)
	24-hour[b]	0.14 ppm (365 µg/m³)		

[a] Parenthetical value is an approximately equivalent concentration.

[b] Not to be exceeded more than once per year.

[c] The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than one, as determined according to Appendix H of the Ozone NAAQS.

[d] Particulate standards use PM-10 as the indicator pollutant. The annual standard is attained when the expected annual arithmetic mean concentration is less than or equal to 50 µg/m³; the 24-hour standard is attained when the expected number of days per calendar year above 150 µg/m³ is equal to or less than one, as determined according to Appendix K of the PM NAAQS.

Most trends information presented in this report is based on data from two principal indicators:

- Measurements of pollutant concentrations in the ambient air.
- Estimates of total national pollutant emissions.

National trends in air quality are derived from routine measurements recorded over time at monitoring sites located primarily in urban and suburban areas, and to a lesser extent in selected rural areas. These monitoring stations are operated by state, tribal, and local government agencies as well as some federal agencies. The national air quality trends calculated for this report were derived from the composite average of direct measurements of air concentrations obtained from ambient air quality monitoring sites (see Table A-10). The averaging times and air quality statistics used in these trends calculations relate directly to national ambient air quality standards.

EPA uses the most recent 10 years as the focus of ambient air pollution trends. Because it is important to base analyses of ambient trends on a consistent database, EPA selected a moving 10-year time frame to help avoid inconsistences in the data as a result of changes in the monitoring network (i.e. adding and discontinuing sites and/or changing monitoring methods). It is also informative to investigate trends over a 15 or 20 year time frame. However, the limited amount of data available in the earliest years of monitoring make these long-term trends suitable only for examining the general behavior of ambient concentrations. In addition to 10-year trends and long-term trends, EPA also analyzes one-year changes in ambient concentrations. One-year changes can be used to inform discussions of recent and future trends as well as current conditions but can also be heavily influenced by meteorological conditions.

Specific monitoring sites are included in the 10-year trend analysis only if they have complete data for a minimum of eight out of the 10 years. In 1987, the standard for Total Suspended Particulates (TSP) was replaced with the PM-10 standard. Therefore, PM-10 trend analyses are based on data collected at monitoring sites that have complete data for seven out of eight years between 1988 and 1995. This report contains data accumulated on criteria pollutants between 1986 and 1995 from 4800 monitoring stations around the country.

Another indicator of air quality trends is the estimated total of nationwide emissions. This estimate is based on engineering calculations of the amounts and kinds of pollutants emitted by automobiles, factories, and other sources over a given period.[1] There are also monitors known as continuous emissions monitors (CEMs) that have recently been installed at major electric utilities to measure actual emissions. This report incorporates data from CEMs collected between 1994 and 1995 for NOx and SO2 emissions at major electric utilities.

Although air pollutant concentrations can only be reduced over time by decreasing or eliminating pollutant emissions, changes in pollutant concentrations do not always track changes in pollutant emissions resulting from human activities. There are four primary reasons for the differences observed between trends in concentrations and trends in emissions estimates. First, because most monitors are positioned in urban, population-oriented locales, air quality trends are more likely to track changes in urban emissions rather than changes in total national emissions. Urban emissions are generally dominated by mobile sources, while rural areas may be dominated by large stationary sources such as power plants and smelters. Second, emissions for some pollutants are calculated or measured in a different form than the primary air pollutant. For example, concentrations of NO_2 are caused by emissions of oxides of nitrogen which include nitric oxide and NO_2. Also, concentrations of O_3 are caused by emissions of volatile organic compounds (VOCs) and oxides of nitrogen. Third, the amount of some pollutants measured at monitoring locations depends on what chemical reactions, if any, occur in the atmosphere during the time it takes the pollutant

to travel from its source to the monitoring station. Fourth, meteorological conditions often control the formation and buildup of pollutants in the ambient air. For example, peak O_3 concentrations typically occur during hot, dry, stagnant summertime conditions (i.e., high temperature and strong solar insolation). In contrast, CO is predominately a cold weather problem with peak CO concentrations occurring during the winter months. The temporal variation in particulate levels may also be attributed to fluctuations in meteorological conditions, especially precipitation. Rainfall has the effect of reducing re-entrainment of particles and washing particles out of the air. Also, drier conditions are associated with an increase in the frequency of forest fires.

Carbon Monoxide (CO)

- **Air Quality Concentrations**
  1986–95 37% decrease
  1994–95 10% decrease

- **Emissions**
  1986–95 16% decrease
  1994–95 7% decrease

Nature and Sources

CO is a colorless, odorless, poisonous gas formed when carbon in fuels is not burned completely. It is a product of motor vehicle exhaust, which contributes about 60 percent of all CO emissions nationwide. In cities, as much as 95 percent of all CO emissions emanate from automobile exhaust. These emissions can result in high concentrations of CO, particularly in areas with heavy traffic congestion. Other sources of CO emissions include industrial processes, non-transportation fuel combustion, and natural sources such as wildfires. Peak CO concentrations typically occur during the colder months of the year when CO automotive "cold start" emissions are greater and nighttime inversion conditions are more frequent. Despite an overall downward trend in concentrations and emissions of CO, six metropolitan areas failed to meet the CO NAAQS in 1995.

Health Effects

CO enters the bloodstream and reduces oxygen delivery to the body's organs and tissues. The health threat from CO is most serious for those who suffer from cardiovascular disease. At higher levels of exposure, healthy individuals are also affected. Visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks are all associated with exposure to elevated CO levels. There are two primary NAAQS for ambient CO, a 1-hour average of 35 ppm and an 8-hour average of 9 ppm. These standards cannot be exceeded more than once per year.

Trends

Long-term improvements continued between 1986 and 1995. Figure 2-1 indicates that national average CO levels decreased 37 percent during the past 10 years as measured by the composite average of the annual second highest 8-hour concentration. These reductions in ambient CO levels occurred despite a 31 percent increase in vehicle miles traveled. Nationally, the composite average of exceedances of the CO NAAQS declined 95 percent since 1986. The large difference between the rate of change in concentrations and the percentage change in exceedances is due to the nature of the exceedance statistic (which is simply a count of a pass/fail indicator).

National total CO emissions decreased 16 percent since 1986 as illustrated in Figure 2-2. Because the urban CO monitoring network is primarily mobile-source oriented, the national CO air quality decrease of 37 percent more closely tracks the estimated 20 percent reduction in highway vehicle emissions. Figure 2-3 shows that all transportation sources now account for 81 percent of the nation's total CO emissions.

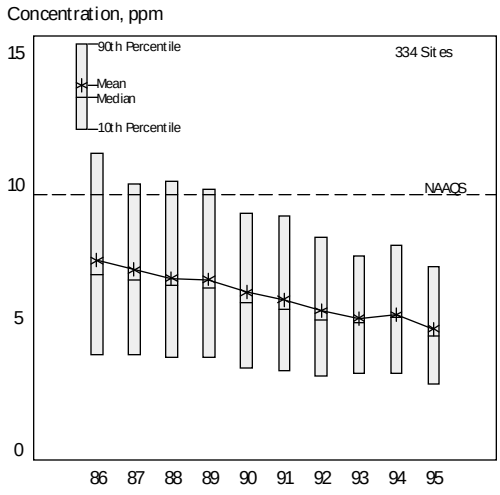


Figure 2-1. *Trend in second maximum non-overlapping 8-hour average CO concentrations, 1986–1995.*

The CO air quality improvement occurred across all monitoring environments—urban, suburban and rural monitoring sites. Figure 2-4 shows, as expected, that urban monitoring sites record higher CO concentrations, on average, than suburban sites, with the lowest levels found at the nine rural CO sites. During the past 10 years, composite mean CO 8-hour concentrations decreased 38 percent at 183 urban sites, 33 percent at 139 suburban locations, and 46 percent at nine rural sites.

Between 1994 and 1995, national average CO concentrations decreased 10 percent, while the average number of exceedances declined 50 percent. All 10 regions of the country experienced declines in composite mean ambient CO levels between 1994 and 1995. The 1995 national composite average ambient concentration is consistent with the long-term ambient CO trend and reverses the one year upturn in 1994 which coincided with the much colder than normal winters in the northeastern and north central regions of the country. Total CO emissions decreased 7 percent since 1994, while CO emissions from highway vehicles declined 5 percent since last year. These improvements in highway vehicle emissions are offset to some extent by the 4 percent increase in emissions from industrial processes.

The Clean Air Act Amendments (CAAA) of 1990 require oxygenated gasoline programs in a number of areas during the winter months to reduce tail pipe emissions of CO. A minimum oxygen content of 2.7% by weight is required in the gasoline to help burn the fuel more completely.[1,2] Areas are required to implement the program to help reach attainment of the federal CO standard. Thirty-six nonattainment areas implemented the program in 1992. Several areas since then have attained the standard, with 28 areas currently remaining in the program.

The map in Figure 2-5 shows the variations in CO concentrations across the country in 1995. The air quality indicator is the highest annual second maximum 8-hour concentration measured in each county. The bar chart to the left of the map displays the number of people living in counties within each concentration range. The colors on the map and bar chart correspond to the colors for the concentration ranges dis-

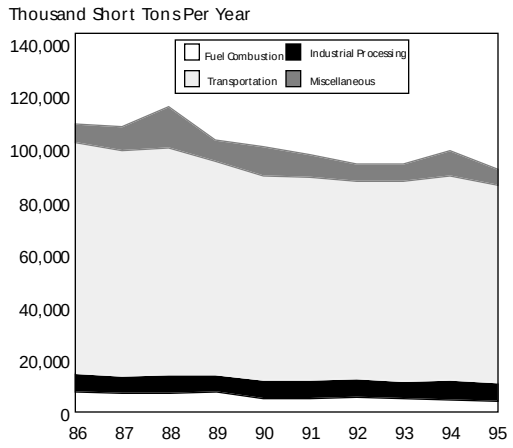


Figure 2-2. *National total CO emissions trend, 1986–1995.*

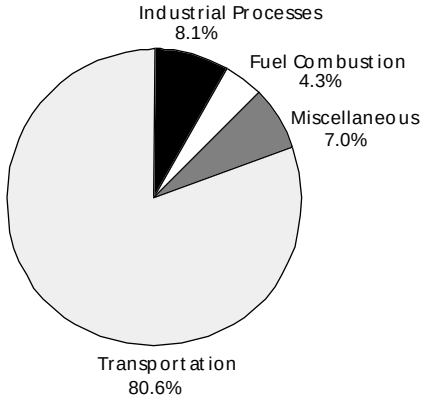


Figure 2-3. *CO emissions by source category, 1995.*

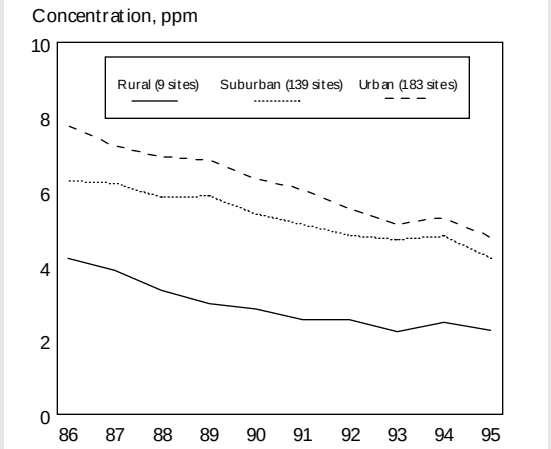


Figure 2-4. *CO second maximum 8-hour concentration trends by location, 1986–1995.*

played in the map legend. In 1995, six counties (with a total population of approximately 12 million) had second maximum 8-hour concentrations greater than 9 ppm. This is a decrease from 10 counties with a total population of 15 million people in 1994.

Figure 2-6 illustrates the improvement in ambient CO air quality during the past 20 years. Although there are differences in the mix of trend sites for the two periods (147 vs. 334 sites), there is evidence of a consistent decline in CO concentrations during the past 20 years.

The CO ambient trends plotting points and emissions totals by source category are listed in Tables A-1 and A-2. The plotting points for the 20-year trend charts are listed in Table A-9.

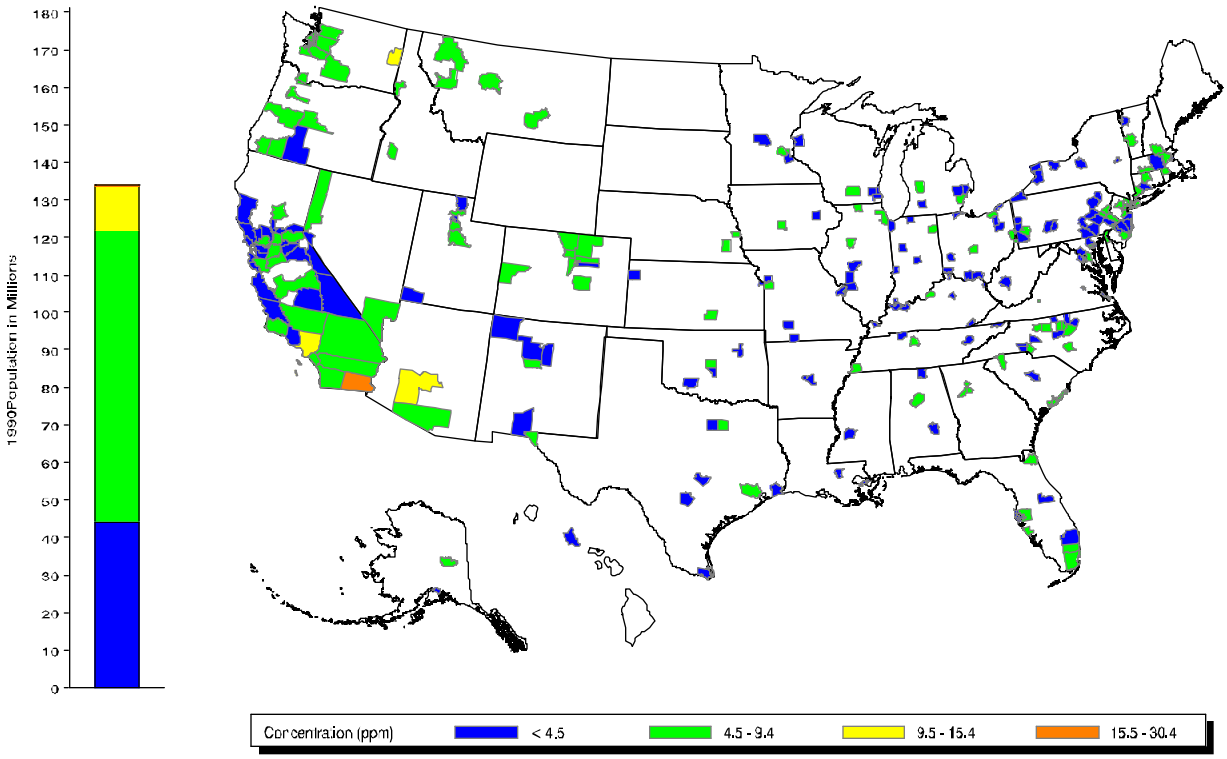


Figure 2-5. *Highest CO second maximum 8-hour concentration by county, 1995.*

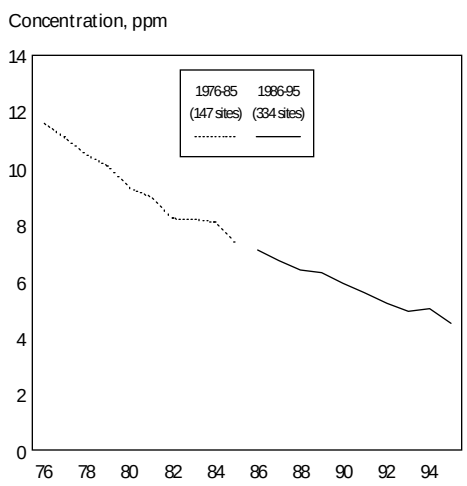


Figure 2-6. *Long-term ambient CO trend, 1976–1995.*

Lead (Pb)

- **Air Quality Concentrations**
  1986–95 78% decrease
  1994–95 no change

- **Emissions**
  1986–95 32% decrease
  1994–95 1% decrease

Nature and Sources

In the past, automotive sources were the major contributor of lead emissions to the atmosphere. As a result of EPA's regulatory efforts to reduce the content of lead in gasoline, the contribution from the transportation sector has declined. Today, smelters and battery plants, followed by highway vehicles, are the major sources of lead emissions to the atmosphere. The highest concentrations of lead are found in the vicinity of nonferrous smelters and other stationary sources of lead emissions.

Health Effects

Exposure to lead mainly occurs through the inhalation of air and the ingestion of lead in food, water, soil, or dust. It accumulates in the in the blood, bones, and soft tissues. Because it is not readily excreted, lead can also affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause neurological impairments such as seizures, mental retardation, and / or behavioral disorders. Even at low doses, lead exposure is associated with changes in fundamental enzymatic, energy transfer, and homeostatic mechanisms in the body. At low doses, fetuses and children often suffer from central nervous system damage. Recent studies show that lead may be a factor in high blood pressure and subsequent heart disease. The primary NAAQS for lead is a quarterly average concentration not to exceed 1.5 $\mu g / m^3$.

Trends

Figure 2-7 indicates that between 1986 and 1995, maximum quarterly average lead concentrations decreased 78 percent; Figure 2-8

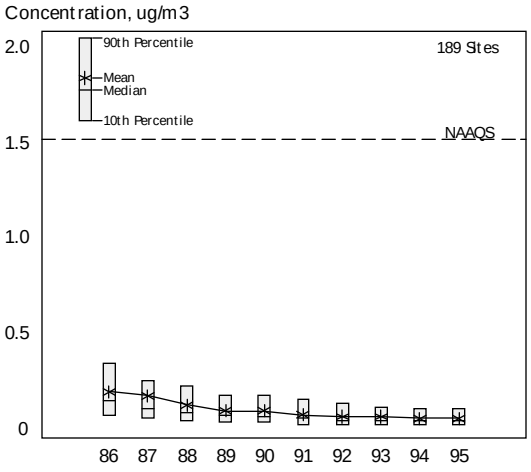


Figure 2-7. *Trend in maximum quarterly average Pb concentrations, 1986–1995.*

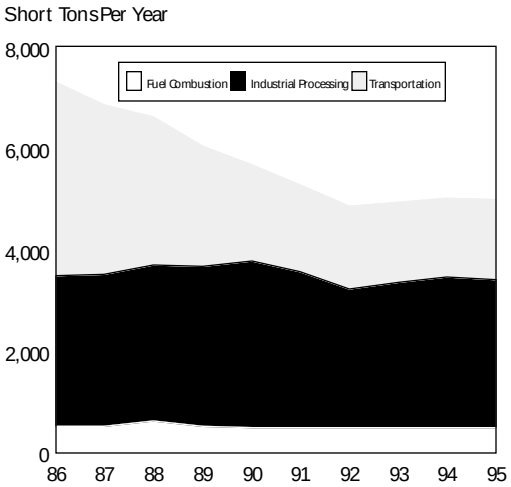


Figure 2-8. *National total Pb emissions trend, 1986–1995.*

shows that total lead emissions decreased 32 percent. These reductions are a direct result of the phase-out of leaded gasoline. Air quality trends at urban and suburban locations over this 10-year period appear to be quite similar according to Figure 2-9, which is not surprising since highway vehicles are the major source of emissions at both of these locations. Table A-3, which lists lead emissions by major source category, shows that highway vehicles accounted for 95 percent of the 10-year lead emissions decline.

The effect of the conversion to unleaded gasoline usage on ambient lead concentrations is even more impressive when viewed over a longer period as illustrated in Figure 2-10. Between 1976 and 1995, ambient concentrations of lead declined 97 percent. Between 1994 and 1995, national average lead concentrations (approaching the minimum detectable level) remained unchanged, while lead emissions declined 1 percent.

The large reductions in long-term lead emissions from transportation sources has changed the nature of the ambient lead problem in the United States. As Figure 2-11 shows, industrial processes were the major source of lead emissions in 1995, accounting for 59 percent of the total, or almost twice the transportation sector contribution of 32 percent. Because industrial processes are now responsible for all violations of the lead standard, the lead monitoring strategy focuses on these point sources of emissions. The map in Figure 2-12 shows the lead monitors oriented in the vicinity of major sources of lead emissions. In 1995, nine lead point sources had one or more site-oriented monitors that exceeded the NAAQS. These nine sources are ranked in Figure 2-12 according to the site with greatest maximum quarterly mean. Various enforcement and regulatory actions are being actively pursued by EPA and the States for these sources.

The map in Figure 2-13 shows the highest quarterly mean lead concentration by county in 1995. Nine counties, with a total population of 4.7 million and containing the point sources from Figure 2-12, did not meet the lead NAAQS in 1995. Note that the point-source oriented monitoring data were excluded from the trends analyses data presented in Figures 2-7 and 2-9.

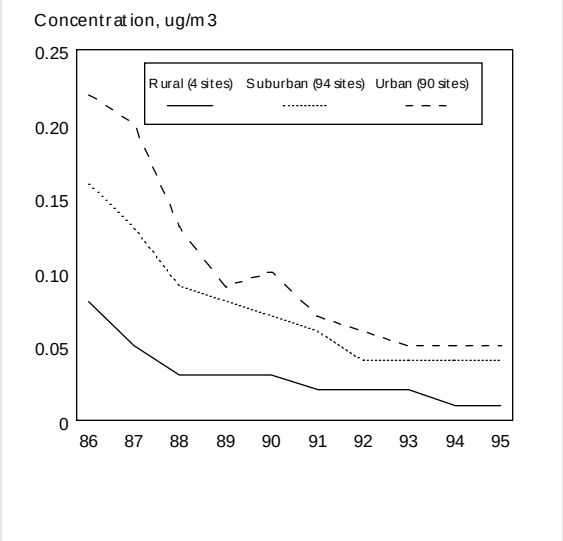


Figure 2-9. *Pb maximum quarterly mean concentration trends by location, 1986–1995.*

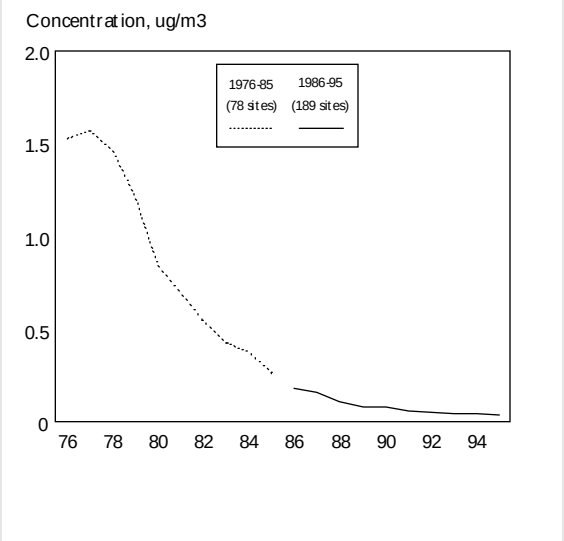


Figure 2-10. *Long-term ambient Pb trend, 1976–1995.*

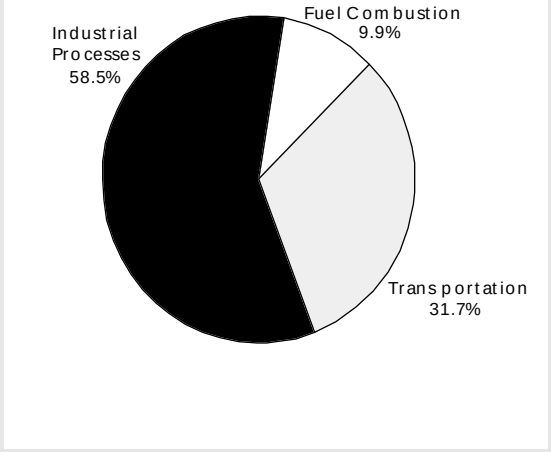
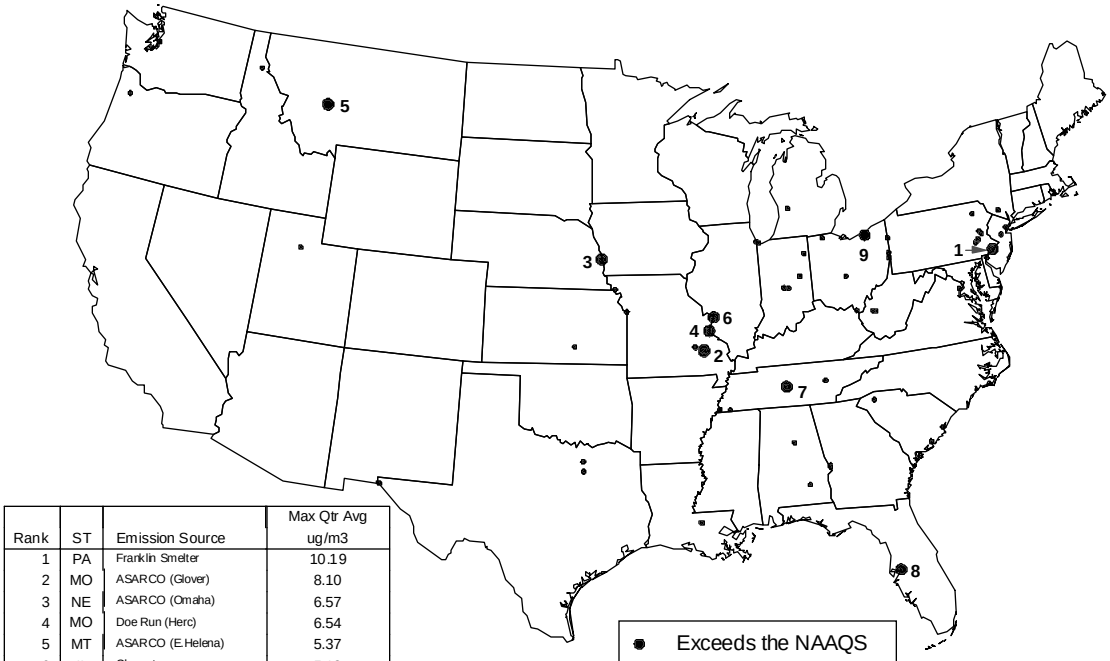


Figure 2-11. *Pb emissions by source category, 1995.*



Rank	ST	Emission Source	Max Qtr Avg ug/m3
1	PA	Franklin Smelter	10.19
2	MO	ASARCO (Glover)	8.10
3	NE	ASARCO (Omaha)	6.57
4	MO	Doe Run (Herc)	6.54
5	MT	ASARCO (E.Helena)	5.37
6	IL	Chemetco	5.18
7	TN	General Smelting	2.92
8	FL	Gulf Cost Lead	2.25
9	OH	Master Metals	1.63

Note: Site markers may overlap.

Figure 2-12. *Pb maximum quarterly concentration in the vicinity of Pb point sources, 1995.*

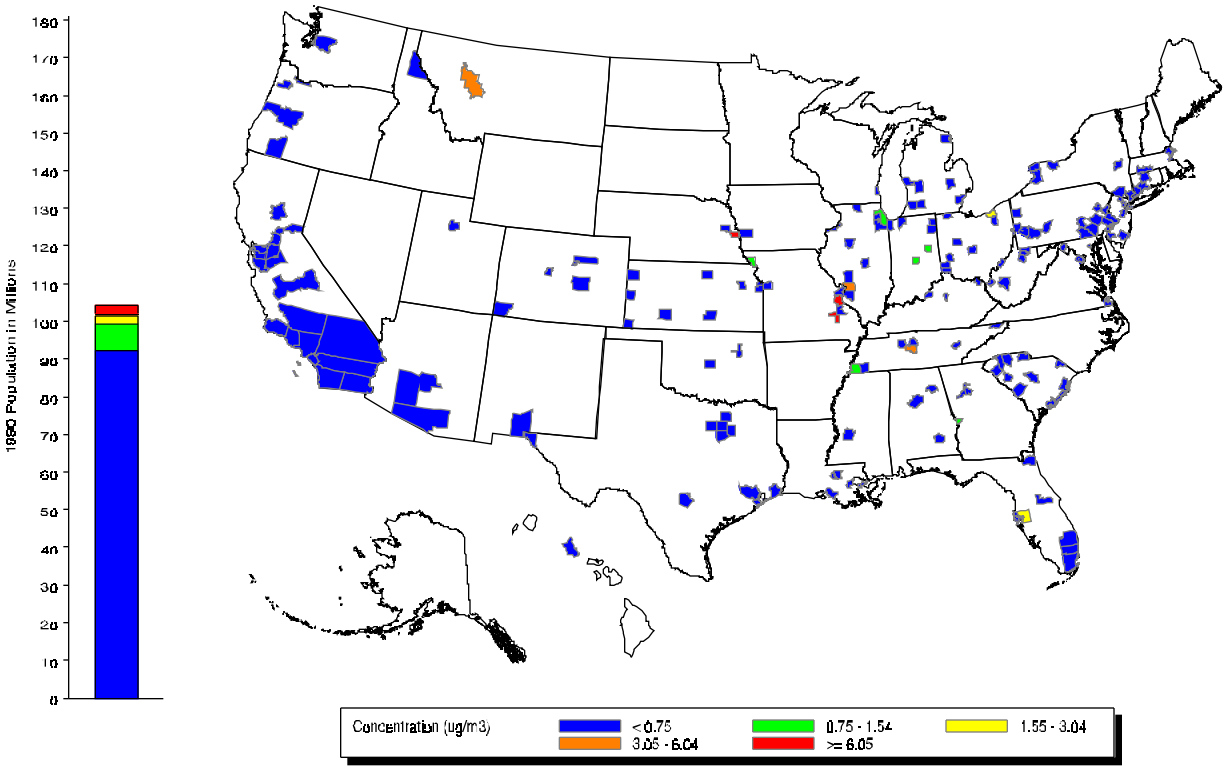


Figure 2-13. *Highest Pb maximum quarterly mean concentration by county, 1995.*

Nitrogen Dioxide (NO_2)

- **Air Quality Concentrations**
  1986–95 14% decrease
  1994–95 5% decrease

- **Emissions**
  1986–95 3% decrease
  1994–95 8% decrease

Nature and Sources

NO_2 belongs to a family of poisonous, highly reactive gases called oxides of nitrogen (NO_x). These gases form when fuel is burned at high temperatures, and come principally from motor vehicle exhaust and stationary sources such as electric utilities and industrial boilers. A suffocating, brownish gas, NO_2 is a strong oxidizing agent that reacts in the atmosphere to form corrosive nitric acid. It also plays a major role in the atmospheric reactions that produce ozone.

Health and Other Effects

NO_2 can irritate the lungs and lower resistance to respiratory infections such as influenza. The effects of short-term exposure are still unclear, but continued or frequent exposure to concentrations higher than those normally found in the ambient air may cause increased incidence of acute respiratory disease in children. The ambient NO_2 primary NAAQS is an annual mean concentration not to exceed 0.053 ppm. Oxides of nitrogen are an important precursor to both ozone and acidic precipitation (acid rain) and may affect both terrestrial and aquatic ecosystems. The regional transport and deposition of nitrogenous compounds arising from emissions of NO_x is a potentially significant contributor to such environmental effects as the growth of algae and subsequent unhealthy or toxic conditions for fish in the Chesapeake Bay and other estuaries. In some parts of the western United States, oxides of nitrogen have a significant impact on particulate matter concentrations.

Trends

Nationally, annual mean NO_2 concentrations remained relatively constant throughout the 1980s, followed by decreasing concentrations in the 1990s. The 1995 composite average of the NO_2 annual mean concentrations is 14 percent lower than the 1986 level, and five percent lower than the 1994 level, as illustrated in Figure 2-14.

The trend in national total emissions of NO_x is shown in Figure 2-15. Between 1986 and 1995, national total NO_x emissions decreased 3 percent. However, between 1994 and 1995 emissions decreased 8 percent. Title IV (Acid Deposition Control) of the 1990 CAAA specifies that between 1980 and 2010 total annual NO_x emissions will be reduced by approximately 10 percent (a reduction of 2 million tons). Although NO_x emissions are not affected by Title IV until 1996, Reasonably Available Control Technology (RACT) conditions must be met in 1995. Thus, low NO_x burners were often

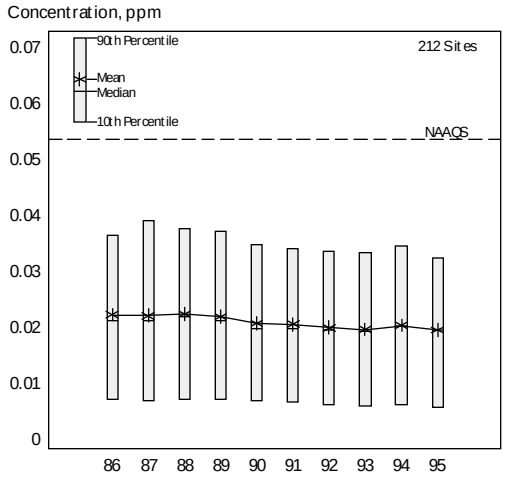


Figure 2-14. *Trend in annual NO_2 concentrations, 1986–1995.*

installed before the required date and are reflected in NO_x emissions declines between 1994 and 1995. In 1995, the two primary sources of the NO_x emissions were fuel combustion (46 percent) and transportation (49 percent) as shown in Figure 2-16. Table A-4 provides a listing of NO_x emissions by major source category.

Although the highest ambient NO_2 levels are typically observed in urban areas, Figure 2-17 shows that the ambient NO_2 air quality trends are similar across monitoring locations. Additionally, 1995 is the fourth consecutive year that all monitoring locations across the nation, including Los Angeles, met the federal NO_2 air quality standard (see Figure 2-18). Twenty-year trends in ambient NO_2 concentrations are not shown because the sites meeting the 1976–1985 completeness criteria (a total of 48 sites) are not representative of the mix of 212 sites in the current trends data base.

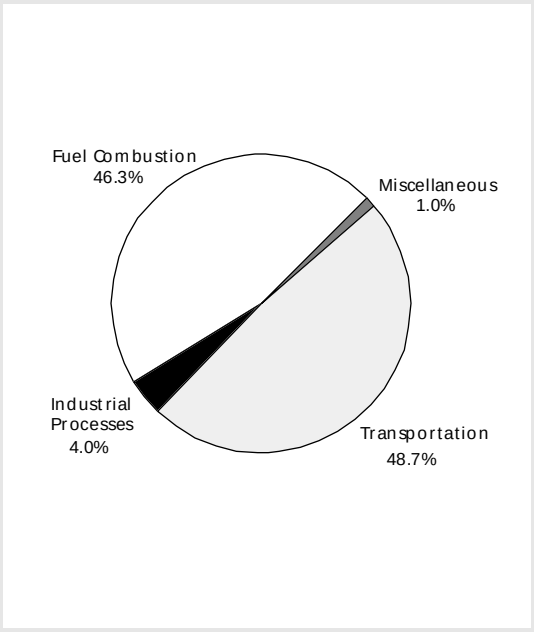


Figure 2-16. *NO_x emissions by source category, 1995.*

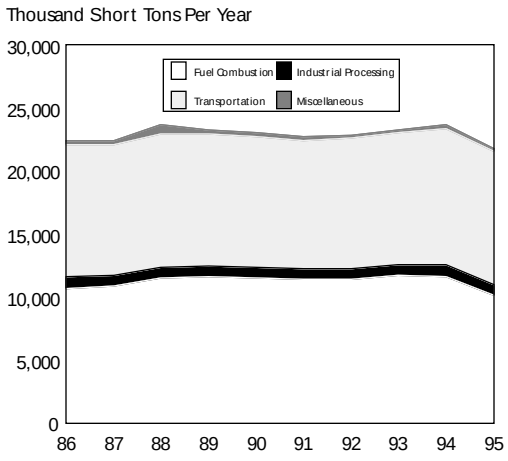


Figure 2-15. *National total NO_x emissions trend, 1986–1995.*

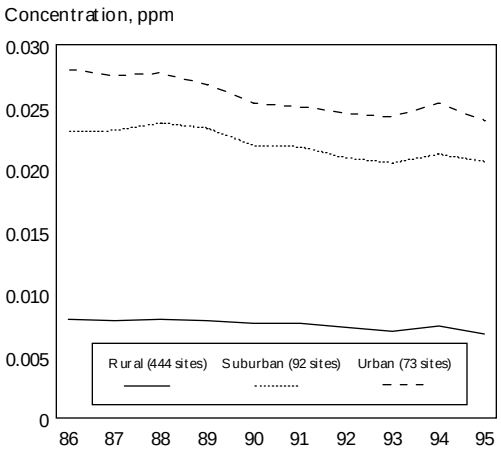


Figure 2-17. *NO_2 annual mean concentration trends by location, 1986–1995.*

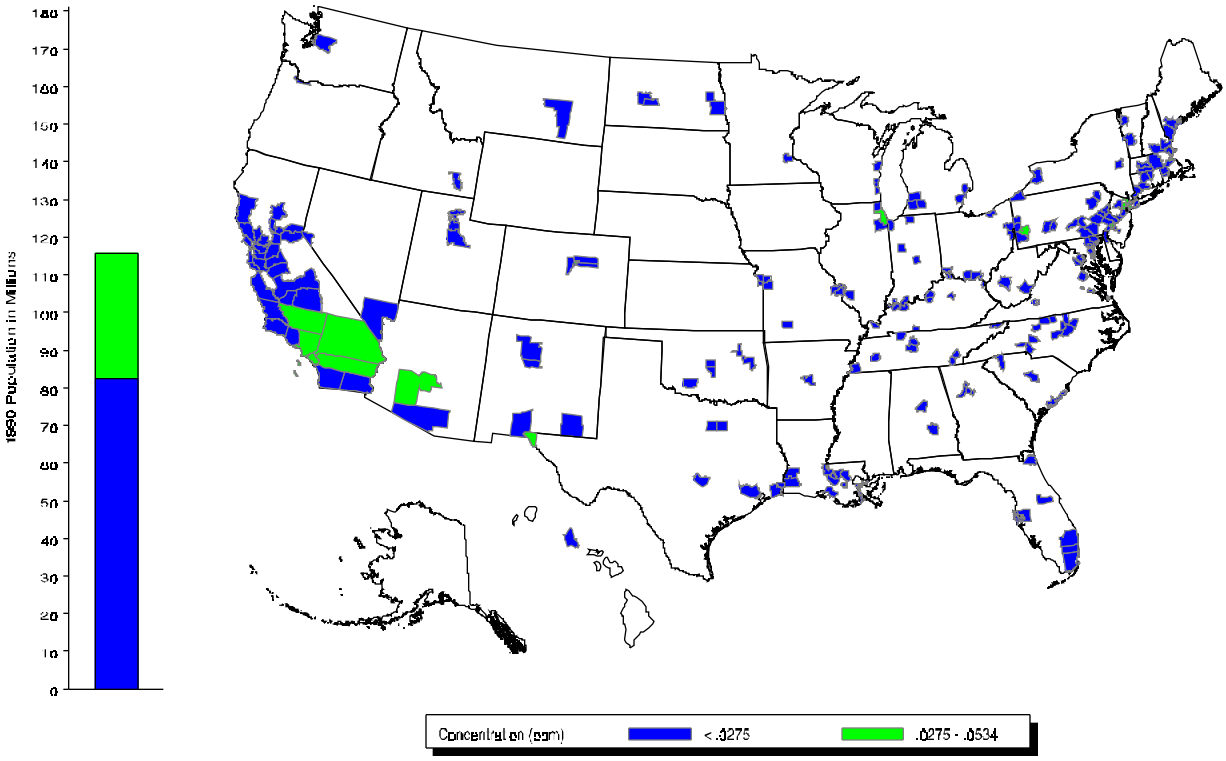


Figure 2-18. *Highest NO_2 annual mean concentration by county, 1995.*

Ozone (O_3)

- **Air Quality Concentrations**
  1986–95 6% decrease
  1994–95 4% increase

- **VOC Emissions**
  1986–95 9% decrease
  1994–95 2% decrease

Nature and Sources

Ground-level O_3 is the most complex, difficult to control, and pervasive of the six criteria pollutants. Unlike other pollutants, O_3 is not emitted directly into the air by specific sources. A poisonous form of pure oxygen, it is created when sunlight reacts with NO_x and VOCs in the air. There are thousands of sources of these gases. Some of the more common sources are gasoline vapors, chemical solvents, combustion products of various fuels, and consumer products. These products can be frequently found in large industrial facilities, gas stations, and small businesses such as bakeries and auto body repair shops. Often these "precursor" gases are emitted in one area, but the actual chemical reactions, stimulated by sunlight and temperature, take place in another. Combined emissions from motor vehicles and stationary sources can be carried hundreds of miles from their origins, forming high O_3 concentrations over very large regions. Approximately 70 million people lived in 108 counties with air quality levels above the primary O_3 NAAQS in 1995. Los Angeles has the highest number of exceedances of the O_3 NAAQS followed by Houston, then metropolitan areas in California and the Northeast.

Health and Other Effects

While O_3 in the upper atmosphere is beneficial in that it shields the earth from harmful ultraviolet rays, ground-level O_3 causes health problems because it damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Scientific evidence indicates that ambient levels of O_3 not only affect people with impaired respiratory systems (such as asthmatics) but healthy adults and children as well. Exposure to O_3 for six to seven hours, even at relatively low concentrations, has been found to significantly reduce lung function and induce respiratory inflammation in normal, healthy people during periods of moderate exercise. This decrease in lung function is often accompanied by such symptoms as chest pain, coughing, nausea, and pulmonary congestion. Recent studies provide evidence of an association between elevated ambient O_3 levels and increases in hospital admissions for respiratory problems in several U.S. cities. Though less well established in humans, animal studies have demonstrated that repeated exposure to O_3 over a period of months or years can produce permanent structural damage in the lungs and accelerate the rate of lung function decline and the aging of the lungs.

Ambient O_3 is also responsible for 1 to 2 billion dollars of agricultural crop yield loss in the United States each year. Because ground-level ozone interferes with the ability of plants to produce and store food, plants are more susceptible to disease, insect attack, other environmental pollutants, and harsh weather, resulting in, for example, yield loss in crops and biomass loss in tree seedlings.

Ozone also damages the foliage of trees and other plants, decreasing the beauty of our national parks and recreation areas, and has an impact on wildlife. For example, O_3 effects can reduce the ability of affected areas to provide habitats to endangered as well as other species. In an example affecting a common species, milkweed, long known for its sensitivity to O_3 and usefulness as an indicator species of elevated O_3 levels, is the sole food of the monarch butterfly larvae. Thus, a major risk associated with the loss of milkweed foliage for a season is that it might have significant indirect effects on the local monarch butterfly population.

Since 1986, over 3,000 new studies have been published on the health and ecological effects of ambient ozone. Many of these studies

indicate that negative effects occur at levels lower than the current ambient standard for ozone. The current standard for O_3 is 0.12 ppm daily maximum 1-hour concentration, not to be exceeded more than once per year averaged over three calendar years.

EPA is currently reviewing the NAAQS for O_3 in accordance with the requirements of the Clean Air Act. The NAAQS for particulate matter is also currently under review (see the PM-10 section of this chapter) and the Agency plans to complete these reviews and propose decisions on whether to retain or revise both NAAQS by November 29, 1996, with final action planned for June 1997.[3] EPA is considering the recommendation of the Clean Air Science Advisory Committee (CASAC) "that the present 1-hour standard be eliminated and replaced with an 8-hour standard."[4]

Trends

Ground level O_3 (the primary constituent of smog) has remained a pervasive pollution problem throughout the United States. Ambient O_3 trends are influenced by year-to-year changes in meteorological conditions, population growth, and VOC to NO_x ratios as well as changes in emissions from ongoing control measures. Meteorological conditions in 1995 were highly conducive to peak O_3 formation, especially in the Midwest and Gulf states and throughout the East. Nationally, 1995 was the 33rd hottest summer in the last 100 years, while 1988 was the 3rd hottest. On a regional basis, the Northeast experienced its 3rd hottest summer, while the Central states had the 11th hottest summer. Figure 2-19 reveals that the 1995 composite national average daily maximum 1-hour O_3 concentration is 6 percent lower than the 1986 composite mean level. The national 1995 composite mean is 4 percent higher than the previous year and the same as the composite level recorded in 1990. The lowest national composite mean level was recorded in 1992 and the highest in 1988. The composite mean of the number of exceedances of the O_3 NAAQS declined 53 percent since 1986. In contrast to

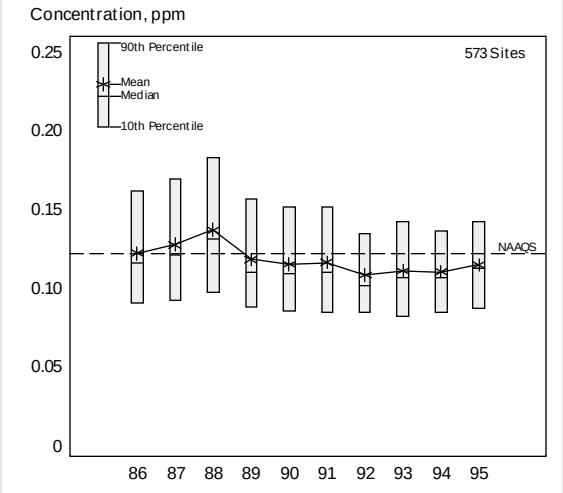


Figure 2-19. *Trend in annual second daily maximum 1-hour O_3 concentrations, 1986–1995.*

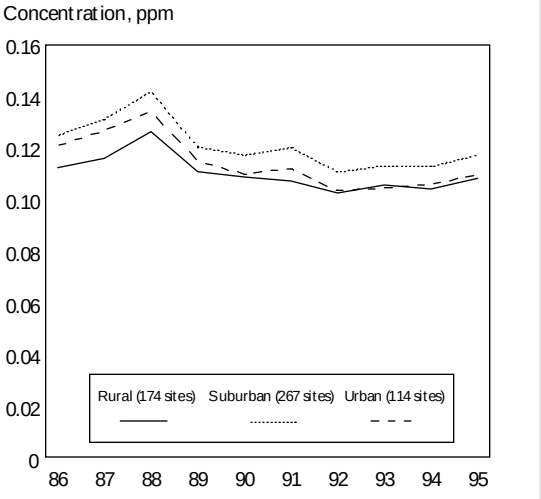


Figure 2-20. *O_3 second daily maximum 1-hour concentration trends by location, 1986–1995.*

the trend in concentrations, the composite mean of the number of exceedances declined 6 percent between 1994 and 1995, primarily as a result of the 24-percent reduction in the number of exceedances at sites in California.

Figure 2-20 shows that the trends in composite mean second daily maximum 1-hour concentrations are similar across monitoring environments, although the highest levels are typically found at suburban sites. During the past 10 years, the composite mean at 114 urban sites recorded the largest air quality improvement (a 9 percent decline in O_3 concentrations), followed by a decrease of 6 percent at 267 suburban sites, while O_3 levels declined 4 percent at 174 sites in rural locations.

As noted in a study by the National Academy of Science, and in previous Trends Reports, O_3 trends are affected by changing meteorological conditions that are conducive to O_3 formation.[5] EPA has developed a statistical model that attempts to factor out

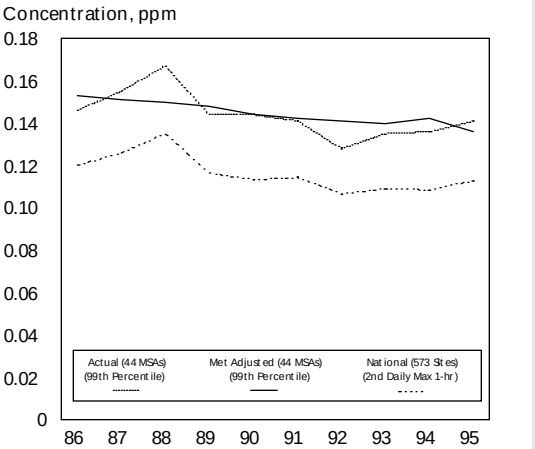


Figure 2-21. *O_3 meteorologically adjusted trend.*

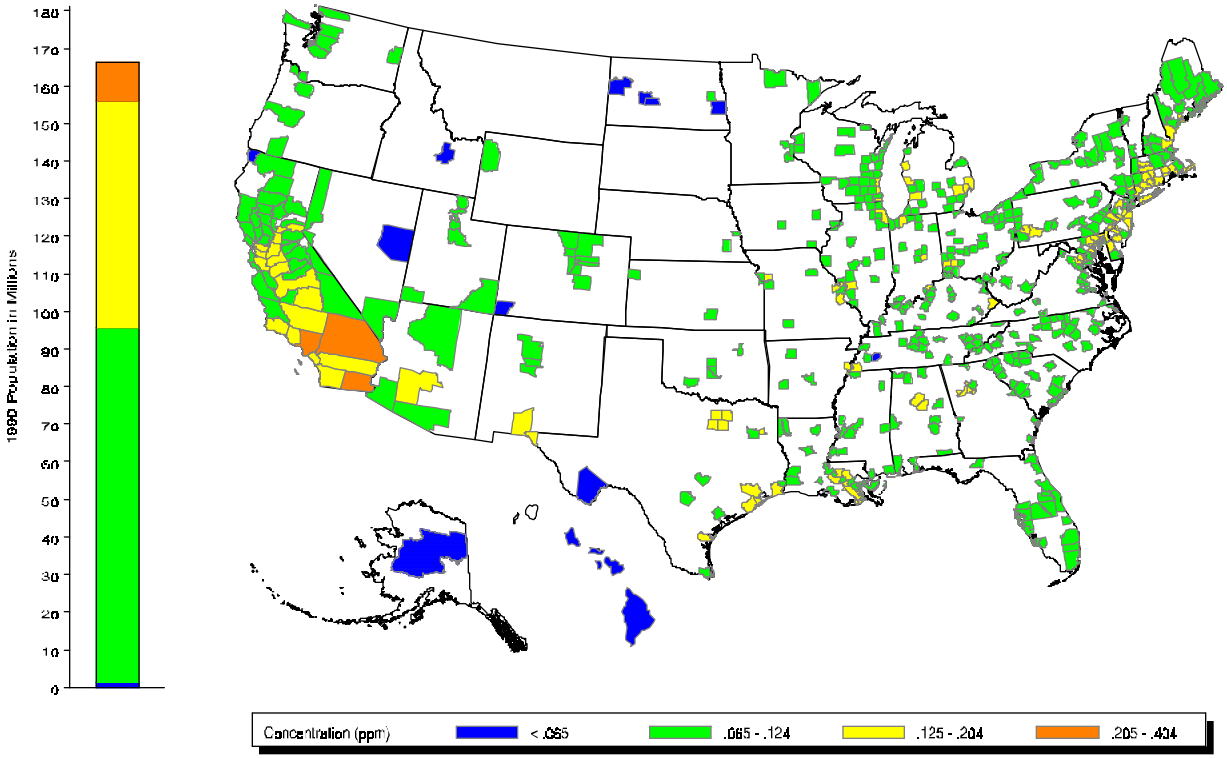


Figure 2-22. *Highest O_3 second daily maximum concentration by county, 1995.*

meteorological effects and helps to normalize the resulting trend estimates across years.[6] Figure 2-21 shows the results from application of the model in 44 major urban areas. While the raw data trends reflect the year-to-year variability in ozone conducive conditions, the meteorologically adjusted O_3 composite trend provides a more stable indicator of O_3 trends. For these 44 metropolitan areas, the adjusted trend shows continued improvement with an average decrease of about 1 percent per year since 1986.

The map in Figure 2-22 presents the highest second daily maximum 1-hour concentration by county in 1995. The accompanying bar chart to the left of the map reveals that in 1995 approximately 70 million people lived in 108 counties where the second daily maximum 1-hour concentration was above the level of the O_3 NAAQS.

Quantitative long-term ambient O_3 trends are difficult to assess due to changes in network design, siting criteria, spatial coverage and monitoring instrument calibration procedures over the past two decades. Figure 2-23 contrasts the 1976–1985 composite trend line based on 178 sites with the current 1986–1995 composite trend line based on 573 sites. Although the overall trend is downward, short-term upturns corresponding to O_3 conducive meteorology are evident. The shaded area in the late 1970s indicates the period corresponding to the old calibration procedure where concentration levels are less certain.

Figure 2-24 shows that emissions of VOCs (which contribute to O_3 formation) decreased 9 percent between 1986 and 1995. Recent control measures to reduce emissions include regulations to lower fuel volatility as well as NO_x and VOC emissions from tailpipes.[7] These measures are reflected in the 23 percent decrease in emissions from transportation sources, and the 31 percent decline in highway vehicle emissions. NO_x emissions (the other major precursor to O_3 formation) decreased 3 percent between 1986 and 1995. Nationally, the two major sources of VOC emissions are industrial processes (58 percent) and transportation sources (37 percent) as shown in Figure 2-25 and in Table A-5.

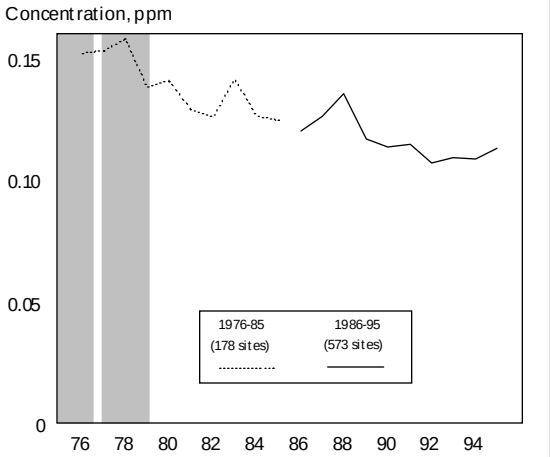


Figure 2-23. *Long-term ambient O_3 trend, 1976–1995.*

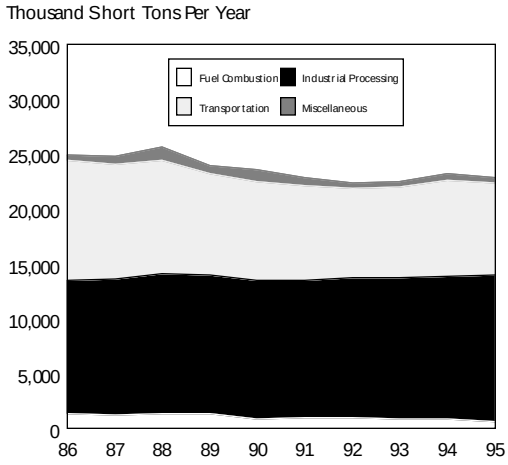


Figure 2-24. *National total VOC emissions trend, 1986–1995.*

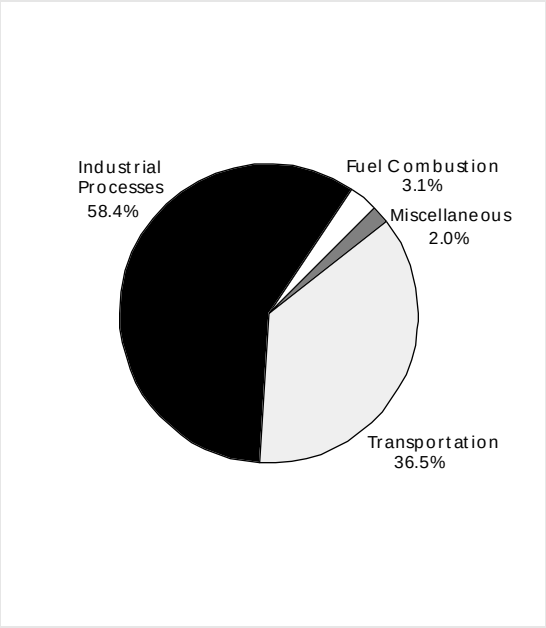


Figure 2-25. *VOC emissions by source category, 1995.*

Because detailed ambient air quality data is useful in understanding the air quality problems of a particular area, the 1990 CAAA called for improved monitoring of ozone and its precursors, VOC and NO_x. Photochemical Assessment Monitoring Stations (PAMS) were therefore developed and positioned in all ozone nonattainment areas classified as serious, severe, or extreme. The 22 affected areas collect measurements of ozone, NO_x, and a number of VOCs as well as surface and upper air meteorology. While the hot dry summer in 1995 resulted in increases in ozone levels in many parts of the country between 1994 and 1995, the majority of the PAMS sites showed decreases in the concentrations of toxics and ozone-forming VOCs. Under more normal summertime conditions, meteorological conditions such VOC reductions would likely lead to decreases in ozone levels. For a more detailed discussion of the PAMS program and VOC reductions, see Chapter 3 of this Report.

As required by the 1990 CAAA, a cleaner burning fuel known as reformulated gasoline (RFG) has been sold as of January 1, 1995 in those areas of the country with the worst ozone or smog problem. RFG is formulated to reduce automotive emissions of ozone-forming pollutants and toxic chemicals—it is estimated to reduce both VOC and toxic emissions by more than 15%. RFG sold during the summer ozone season has lower volatility than most conventional gasoline. Also, RFG has lower levels of certain compounds that contribute to air pollution and a minimum oxygen content of 2 percent, and a maximum benzene content of 1 percent.[8]

The RFG program is mandated year-round in 10 areas of the country (i.e., Los Angeles, San Diego, Hartford, New York, Philadelphia, Chicago, Baltimore, Houston, Milwaukee, and Sacramento). In addition to these required areas, several other parts of the country exceeding the ozone standard have voluntarily entered into the RFG program.[9] For a more detailed discussion of the RFG program and its impact, see Chapter 3 of this report.

Particulate Matter (PM-10)

- **Air Quality Concentrations**
  1988–95 22% decrease
  1994–95 4% decrease

- **Emissions**
  1988–95 17% decrease
  1994–95 6% decrease

Nature and Sources

Particulate matter is the general term for solid or liquid particles found in the atmosphere. Some particles are large or dark enough to be seen as soot or smoke. Others are so small they can be identified only with an electron microscope. Because particles originate from a variety of mobile and stationary sources, their chemical and physical compositions vary widely depending on location and time of year. In 1987, EPA replaced the earlier Total Suspended Particulate (TSP) standard with a PM-10 standard.[10] The PM-10 standard focuses on smaller particles that are likely to be responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract. PM-10 includes those particles whose aerodynamic size is less than or equal to a standard particle with a diameter of 10 micrometers (0.0004 inches).

Health and Other Effects

Based on studies of human populations exposed to ambient particle pollution (sometimes in the presence of SO_2) and laboratory studies of both animals and humans, areas of concern have been identified as: negative effects on breathing and respiratory systems, aggravation of existing respiratory and cardiovascular disease, alterations in the body's defense systems against foreign materials, damage to lung tissue, carcinogenesis, and premature death. The elderly, children, and people with chronic obstructive pulmonary or cardiovascular disease, influenza, or asthma are especially sensitive to the effects of PM-10. In addition, particulate matter serves as a carrier for a variety of toxic metals and compounds, and is a major cause of reduced visibility in many parts of the United States.

There are both short- and long-term PM-10 NAAQS. The long-term standard specifies an expected annual arithmetic mean not to exceed 50 $\mu g/m^3$, while the short-term 24-hour standard of 150 $\mu g/m^3$ is not to be exceeded more than once per year.

EPA is currently reviewing the NAAQS for particulate matter in accordance with the requirements of the Clean Air Act. Under consideration is a new standard for the fine particles within PM-10 due to epidemiological evidence suggesting stronger associations of mortality and some morbidity effects with fine particles. A decision on whether to retain or revise the NAAQS for PM will be made by November 29, 1996, and final action is scheduled for mid-1997.[3]

Trends

Ambient monitoring networks were revised in 1987 to measure PM-10, so 1988 is the first complete year of PM-10 trends data for most monitors. Figures 2-26 and 2-27 show the change in measured concentrations at monitoring sites and the change in estimated emissions between 1988 and 1995. The national average of annual mean PM-10 concentrations decreased 22 percent, while PM-10 emissions decreased 17 percent. Between 1994 and 1995, mean PM-10 concentrations decreased 4 percent, while PM-10 emissions decreased a comparable 6 percent.

Urban and suburban sites have similar trends and comparable average concentration levels, as shown in Figure 2-28. The trends at rural sites are consistent with these urban and suburban patterns, although the composite mean level is significantly lower.

PM-10 emissions from traditionally inventoried sources decreased 17 percent since 1988. Figure 2-29 shows that the three major categories—fuel combustion, industrial processes, and transportation—contribute almost equally to the total. For the first time in recent years however, emissions in the industrial processes category were slightly higher than those for the fuel combustion category. Industrial process emissions increased 1 percent over 1994 levels, while fuel combustion emissions decreased 12 percent. Within the fuel combustion category, the largest decrease was in residential wood

combustion, which declined more than 25 percent between 1994 and 1995. Table A-6 lists PM-10 emissions estimates from these sources for 1986–1995.

As shown in Figure 2-30, emissions from the traditionally inventoried source categories (fuel combustion, industrial processes, transportation) make up only 6 percent of total PM-10 emissions nationwide. The remaining emissions come from natural sources (wind erosion) and the miscellaneous category, which contains emissions for agriculture and forestry, wildfires and managed burning, and fugitive dust from paved and unpaved roads. Of these, fugitive dust makes up the greatest share of all PM-10 emissions (68 percent), followed by agriculture and forestry (20 percent). Miscellaneous and natural source PM-10 emissions estimates are provided in Table A-7.

The map in Figure 2-31 displays the highest second maximum 24-hour PM-10 concentration by county in 1995. When both the annual and 24-hour standards are considered, there were 24 million people living in 22 counties with PM-10 concentrations above the PM-10 NAAQS in 1995.

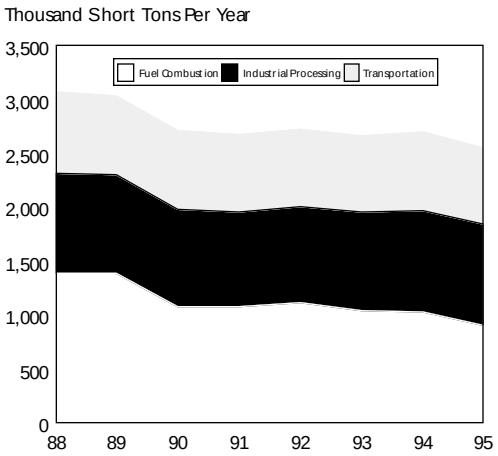


Figure 2-27. *National total PM-10 emissions trend, 1988–1995 (traditionally inventoried sources only).*

Note: These emissions estimates do not include estimates of particulate matter from secondary particle formation in the atmosphere.

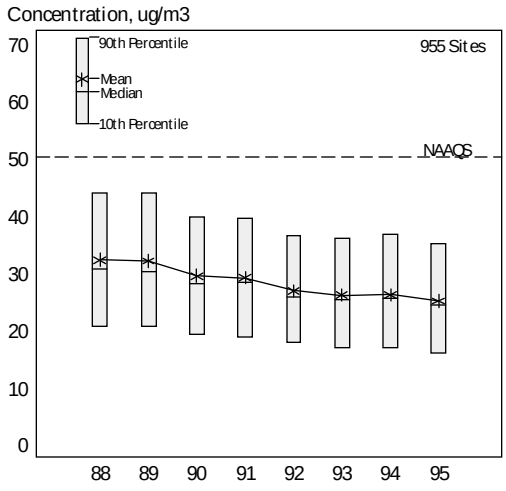


Figure 2-26. *Trend in annual mean PM-10 concentrations, 1988–1995.*

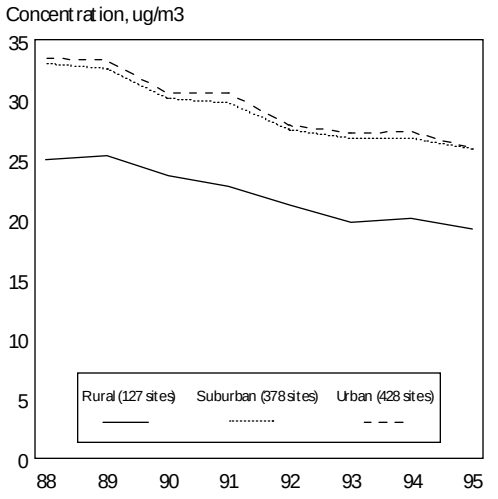


Figure 2-28. *PM-10 annual mean concentration trends by location, 1988–1995.*

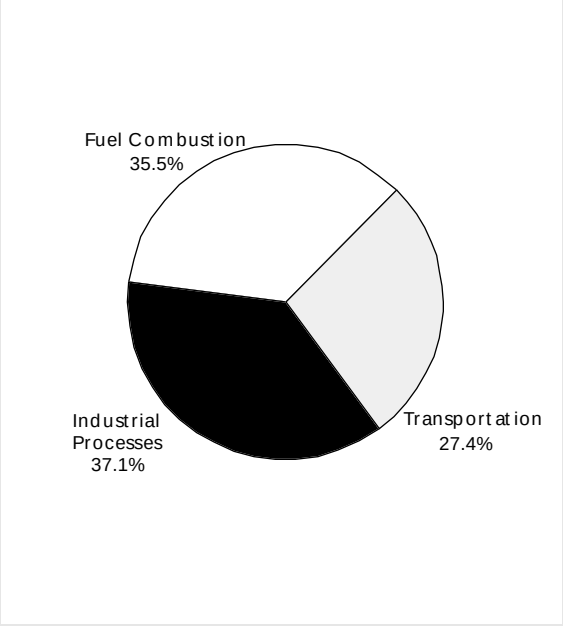


Figure 2-29. *PM-10 emissions from traditionally inventoried source categories, 1995.*

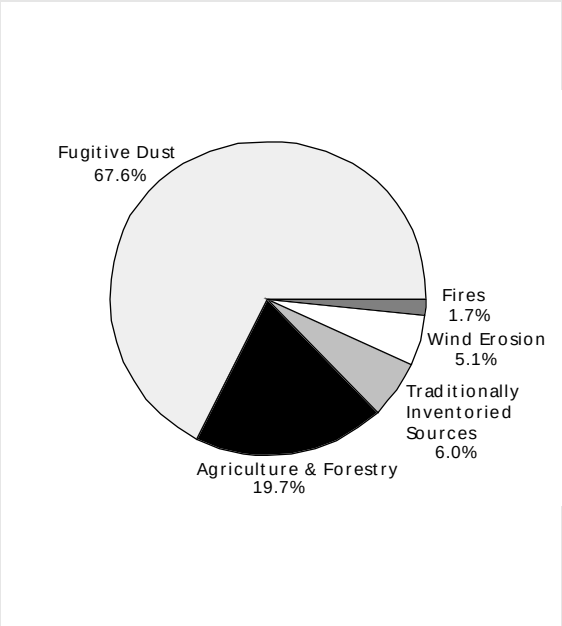


Figure 2-30. *PM-10 total emissions by source category, 1995.*

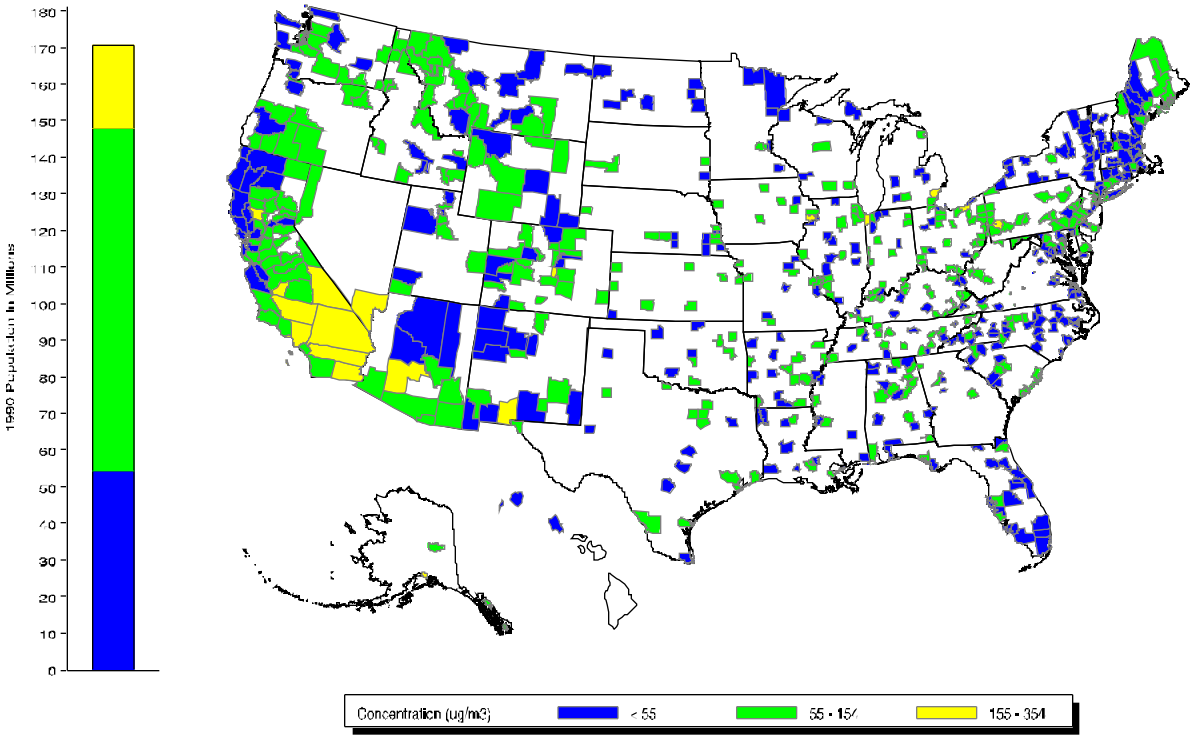


Figure 2-31. *Highest second maximum 24-hour PM-10 concentration by county, 1995.*

Sulfur Dioxide (SO_2)

- **Air Quality Concentrations**
  1986–95 37% decrease
  1994–95 17% decrease

- **Emissions**
  1986–95 18% decrease
  1994–95 13% decrease

Nature and Sources

SO_2 belongs to the family of sulfur oxide gases (SO_x). These gases are formed when fuel containing sulfur (mainly coal and oil) is burned, and during metal smelting and other industrial processes. Most SO_2 monitoring stations are located in urban areas. The highest monitored concentrations of SO_2 are recorded in the vicinity of large industrial facilities.

Health and Other Effects

The major health concerns associated with exposure to high concentrations of SO_2 include effects on breathing, respiratory illness, alterations in the lungs' defenses, and aggravation of existing cardiovascular disease. Major subgroups of the population that are most sensitive to SO_2 include asthmatics and individuals with cardiovascular disease or chronic lung disease (such as bronchitis or emphysema) as well as children and the elderly. There are two primary NAAQS for SO_2 that address these health concerns: an annual mean concentration of 0.030 ppm (80 $\mu g / m^3$) not to be exceeded, and a 24-hour daily concentration of 0.14 ppm (365 $\mu g / m^3$) not to be exceeded more than once per year.

SO_2 also can produce damage to the foliage of trees and agricultural crops. Together, SO_2 and NO_x are the major precursors to acidic deposition (acid rain), which is associated with the acidification of lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility. The secondary SO_2 NAAQS, which protects against such damage, is a 3-hour average concentration of 0.50 ppm (1300 $\mu g / m^3$) not to be exceeded more than once per year.

Trends

The map in Figure 2-32 displays the highest second maximum 24-hour SO_2 concentration by county in 1995. There were no counties containing major SO_2 point sources that failed to meet the ambient SO_2 NAAQS in 1995. The national composite average of SO_2 annual mean concentrations decreased 37 percent between 1986 and 1995 (see Figure 2-33), while SO_2 emissions decreased 18 percent (see Figure 2-34). Between 1994 and 1995, national SO_2 mean concentrations decreased 17 percent, and SO_2 emissions decreased 13 percent.

It is important to emphasize that current SO_2 problems in the U.S. are caused by point sources that are usually identified by modeling rather than routing ambient monitoring. Historically, networks are positioned in population-oriented locales. However, 86 percent of total national SO_2 emissions (Figure 2-35), result from fuel combustion sources that tend to be located in less populated areas. Figure 2-36 reveals that composite annual mean concentrations at sites in suburban and urban locations decreased 40 and 41 percent, respectively, while ambient levels decreased 23 percent at rural sites. The progress in reducing ambient SO_2 concentrations during the past 20 years is portrayed in Figure 2-37. This reduction was accomplished by installing flue-gas control equipment at coal-fired generating plants, reducing emissions from industrial processing facilities such as smelters and sulfuric acid manufacturing plants, reducing the average sulfur content of fuels burned, and using cleaner fuels in residential and commercial burners.

In accordance with the Clean Air Act (CAA), EPA has reviewed and revised the air quality criteria upon which the existing NAAQS for sulfur oxides are based. EPA's final decision was that revisions of the NAAQS for sulfur oxides were currently not appropriate, aside from several minor technical changes.

Initiated by Title IV of the 1990 CAAA, the Acid Rain Program specifies that between 1980

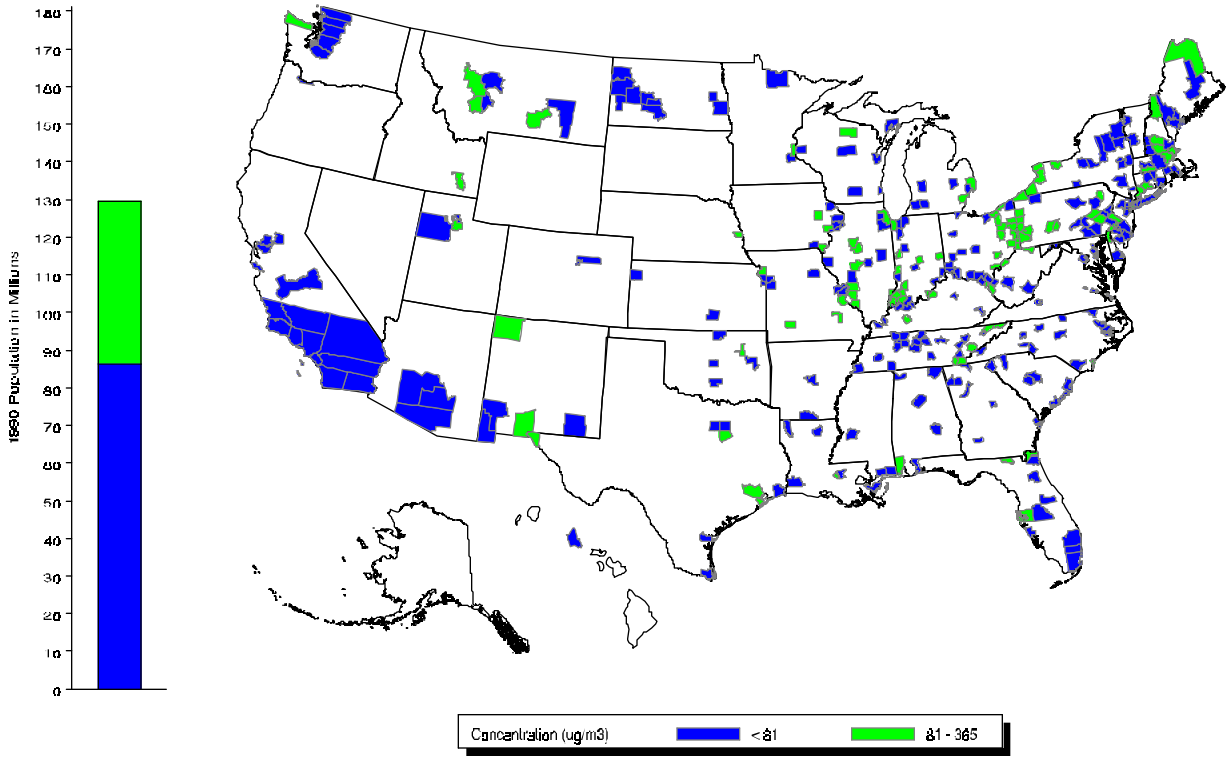


Figure 2-32. *Highest second maximum 24-hour SO_2 concentration by county, 1995.*

and 2010, total annual SO_2 emissions will be reduced by approximately 40 percent (10 million tons). The program will establish a new approach to environmental protection through the use of market incentives. The program sets a permanent cap on the total amount of SO_2 that may be emitted by electric utilities nationwide. The program is being implemented in two phases: Phase I began in 1995, will last until 1999, and currently involves 445 utility units; Phase II begins in 2000 and is expected to involve over 2000 units.[11]

For the 445 units participating in Phase I, actual emissions measured by continuous emissions monitoring systems were reduced by more than half relative to 1980 levels with emissions plummeting from 10.9 to 5.3 million tons. Emissions for these units were 3.4 million tons (or 39 percent) below the 1995 allowable emissions level of 8.7 million tons required by the 1990 CAAA.[11]

Many utilities installed scrubbers earlier than required since it was much less expensive

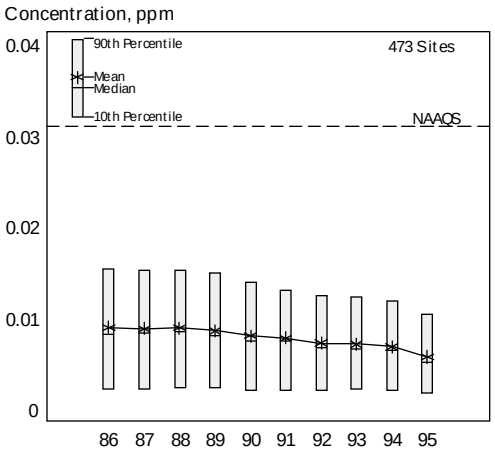


Figure 2-33. *Trend in annual mean SO_2 concentrations, 1986–1995.*

than previously thought. Other utilities switched to lower sulfur coal and also learned that the cost was not prohibitive. Utilities also participated in the annual allowance auctions held in March 1994, 1995, and 1996, where allowances declined in cost with each succeeding year. Thus, SO_2 compliance was often achieved earlier than EPA had anticipated as reflected by the decline in SO_2 emissions between 1994 and 1995.

According to a recent study prepared by the U.S. Geological Survey, reductions in emissions have resulted in rainfall being less acidic in 1995 due to the first year of implementation of the Acid Rain Program. The study reports a 10 to 25 percent drop in rainfall acidity.[11]

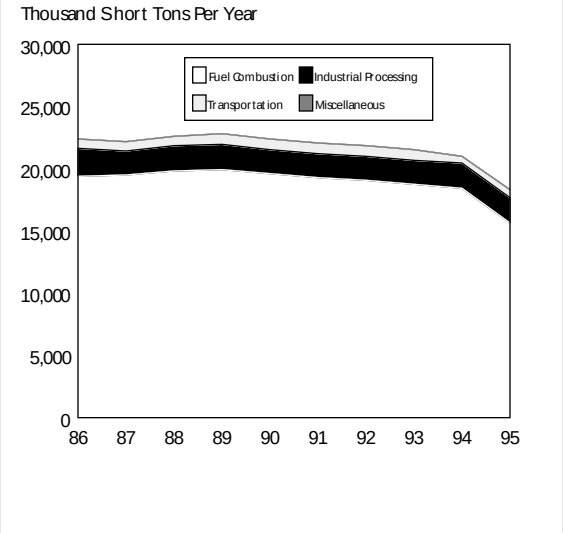


Figure 2-34. *National total SO_2 emissions trend, 1986–1995.*

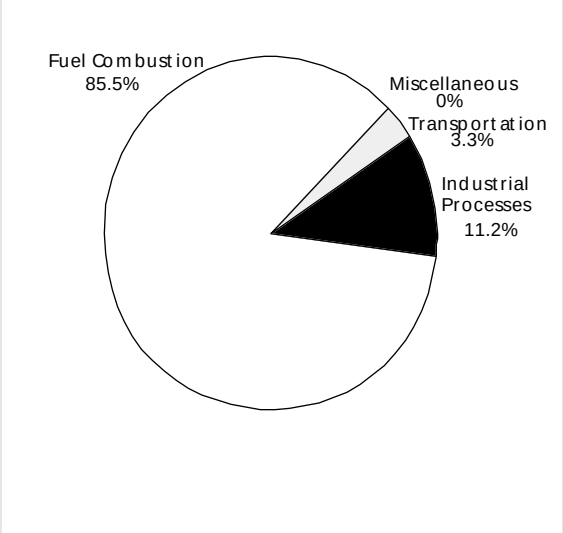


Figure 2-35. *SO_2 total emissions by source category, 1995.*

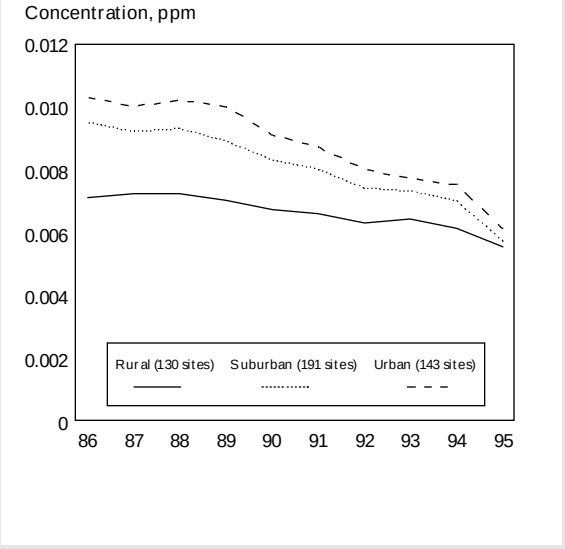


Figure 2-36. *SO_2 annual mean concentration trends by location, 1986–1995.*

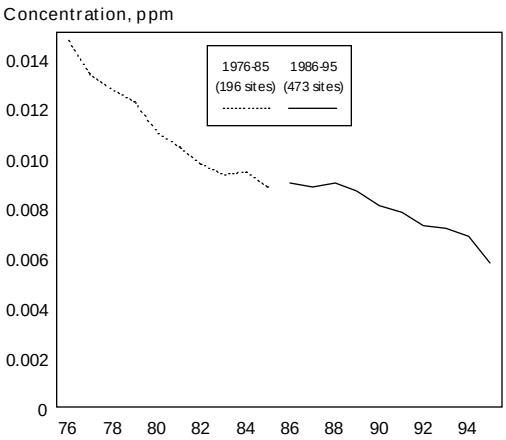


Figure 2-37. *Long-term ambient SO_2 trend, 1976–1995.*

Visibility

Nature and Sources of the Problem

Visibility impairment occurs as a result of the scattering and absorption of light by particles and gases in the atmosphere. It is most simply described as the haze which obscures the clarity, color, texture, and form of what we see. The same particles linked to serious health effects [sulfates, nitrates, organic carbon, soot (elemental carbon), and soil dust] can significantly affect our ability to see.

Both primary and secondary particles contribute to visibility impairment. Primary particles, such as dust from roads and agricultural operations or elemental carbon from diesel and wood combustion, are emitted directly into the atmosphere. Secondary particles are formed in the atmosphere from primary gaseous emissions. Secondary particles of concern include sulfate formed from sulfur dioxide emissions, nitrates from nitrogen oxide emissions, and carbon-based particles formed from hydrocarbon emissions. Reduced visibility is primarily attributable to airborne particles, particularly those less than a few micrometers, in diameter, whereas the only primary gaseous pollutant that directly reduces visibility is nitrogen dioxide.

High relative humidity can significantly increase the effect of pollution on visibility. Some particles, such as sulfates, accumulate water and grow in size and become more efficient at scattering light. Poor summer visibility in the eastern United States is primarily the result of high sulfate concentrations exposed to high humidity levels.

Visibility conditions are commonly expressed in terms of three mathematically related metrics such as visual range, light extinction, and the deciview. Visual range is the maximum distance at which one can identify a black object against the horizon, and is typically described in miles or kilometers. Light extinction, inversely related to visual range, is the sum of light scattering and absorption by particles and gases in the atmosphere. It is typically expressed in terms of inverse megameters (Mm^{-1}), with larger values representing poorer visibility.

Changes in visual range and light extinction are not proportional to human perception, however. For example, a 5-mile change in visual range can be either very apparent or not perceptible, depending on the base line level of ambient pollution. The deciview was developed to address this situation. It describes perceived visual changes on a linear scale over its entire range, analogous to the decibel scale for sound. Under many scenic conditions, a change of one deciview is considered perceptible by the average person. A deciview of zero represents pristine conditions.

Long-Term Trends

Visibility impairment has been analyzed using data collected since 1960 at 280 monitoring stations located at airports across the country. These stations measure visual range, the maximum distance at which an observer can discern the outline of an object. Visibility trends can be inferred from long-term records of visual range. The maps in Figure 2-38 show U.S. visibility trends derived from such data.[12]

The maps show the amount of haze during the summer months of 1970, 1980, and 1990. The dark blue color represents the best visibility, and red represents the worst visibility. Overall, these maps show that annual average visibility impairment in the eastern United States increased greatly between 1970 and 1980, and decreased slightly between 1980 and 1990. This follows the overall trends in emissions of sulfur oxides during these periods.

IMPROVE Visibility Monitoring Network

In 1987, the IMPROVE (Interagency Monitoring of PROtected Visual Environments) visibility monitoring network was established as a cooperative effort between the EPA, National Park Service, U.S. Forest Service, Bureau of Land Management, U.S. Fish & Wildlife Service, and the states. The network is designed to track progress toward the Clean Air Act's national goal of remedying existing

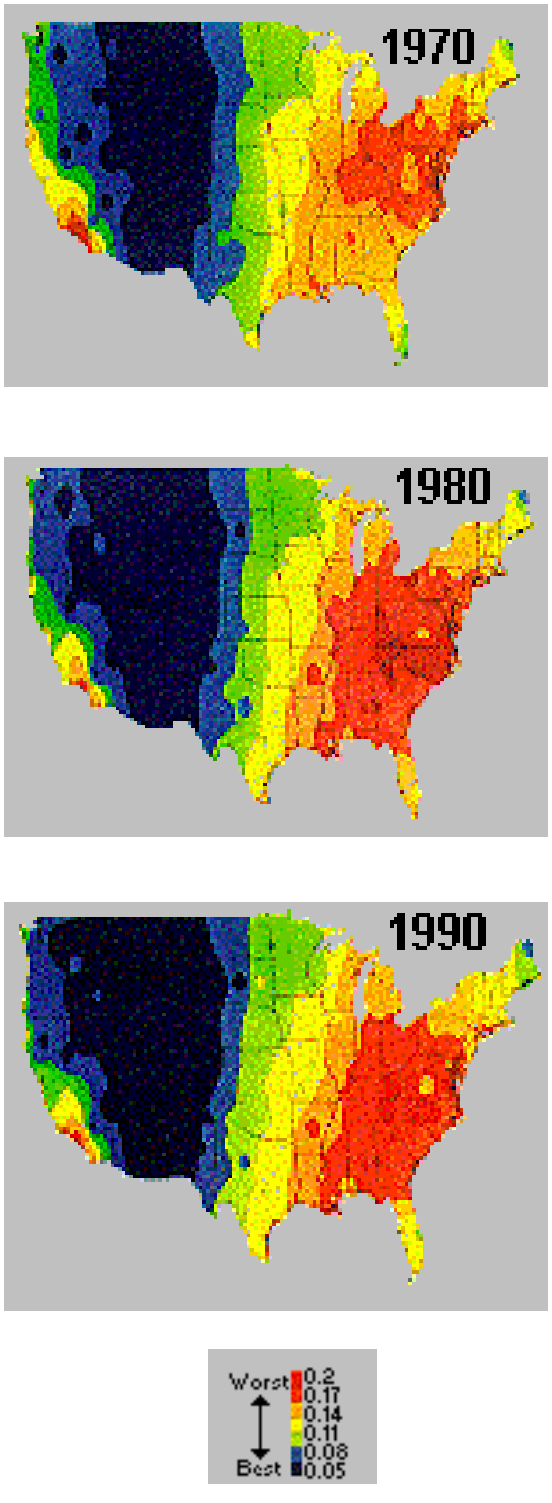


Figure 2-38. *Trend of haze from airport visual data (July–September).*

and preventing future visibility impairment in Class I areas across the country, such as national parks and wilderness areas. It also provides information for determining the types of pollutants and sources primarily responsible for reduced visibility. The network now includes over 40 sites, and uses aerosol, optical, and photographic monitoring methods. It is the largest network in the country devoted to fully characterizing visibility.

Current Conditions

On an annual average basis, natural visibility conditions have been estimated at approximately 80–90 miles in the East and up to 140 miles in the West. Natural visibility varies by region primarily because of higher estimated background levels of fine particles in the East and the more significant effect of relative humidity on particle concentrations in the East than in the West. Current annual average conditions range from about 18–40 miles in the rural East and about 35–90 miles in the rural West.

Figure 2-39 illustrates annual average visibility impairment in terms of light extinction captured at IMPROVE sites between 1992 and 1995. The pie charts show the relative contribution of different particle constituents to visibility impairment. Annual average total light extinction due to these particles is indicated by the value next to each pie and by the size of each pie.[13]

In Figure 2-39, one can see that visibility impairment is generally greater in the rural East compared to most of the West. In the rural East, sulfates account for about 50–70 percent of annual average light extinction. Sulfate plays a particularly significant role in the humid summer months, most notably in the Appalachian, Northeast, and mid-South regions. Nitrates and organic and elemental carbon all account for between 10–15 percent of total light extinction in most Eastern locations.

In the rural West, sulfates also play a significant role, accounting for about 25–40 percent of total light extinction in most regions. However, sulfates account for over 50 percent

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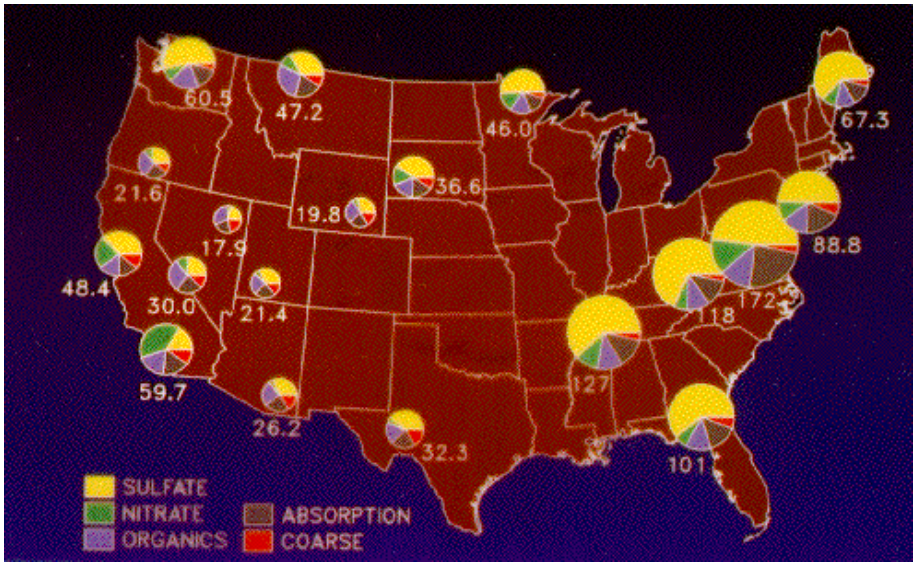

Figure 2-39. *Annual average light extinction (Mm^{-1}), 1992–1995 IMPROVE data.*

of annual average light extinction in the Cascades. Organic carbon typically is responsible for 15–35 percent of total light extinction in the rural West, elemental carbon (absorption) accounts for about 15–25 percent, and soil dust (coarse) accounts for about 10–20 percent. Nitrates typically account for less than 10 percent of total light extinction in Western locations, except in the southern California region, where it accounts for almost 40 percent.

Figure 2-40 also illustrates annual average visibility impairment from IMPROVE data for 1992 to 1995, expressed in deciviews. Note that the deciview scale is more compressed than the scale for visual range or light extinction. Most of the sites in the intermountain West and Colorado Plateau have annual impairment of 12 deciviews or less, whereas many rural locations in the East have values exceeding 23 deciviews.

One key to understanding visibility effects is understanding that the same amount of pollution can have dramatically different effects on visibility depending on existing conditions. It is important to note that visibility in cleaner environments is more sensitive to increases in fine particle concentrations than visibility in more polluted areas. This principle is illustrated in Figure 2-41, which characterizes visibility at Shenandoah National Park under a range of conditions. A clear day at Shenandoah can be represented by a visual range of 80 miles, with conditions approximating naturally-occurring visibility (i.e., without pollution created by human activities). An average day at Shenandoah is represented by a visual range of 18 miles, and is the result of an additional 10 ug/m^3 of fine particles in the atmosphere. The two bottom scenes, with visual ranges of 8 and 6 miles respectively, illustrate that the perceived change in visibility due to an additional 10 ug/m^3 of fine particles to an already degraded atmosphere is much less perceptible than adding this amount to a clean atmosphere. Thus, to achieve a given level of perceived visibility improvement, a larger reduction in fine particle concentrations is needed in more polluted areas. Conversely, a small amount of pollution in a clean area can dramatically decrease visibility.

A recent analysis of data from the IMPROVE network[13] fails to show uniform national trends in sulfur concentration, light absorption (primarily due to soot from fire or diesel combustion), or fine mass concentration. However, some trends can be shown for specific sites during certain seasons. For example, absorption in the winter season has decreased from 1984–1994 at Rocky Mountain and Crater Lake National Parks. A clear demonstration of decreased sulfur concentrations as a result of emissions reductions is found in the desert southwest at Chiricahua National Monument. Absorption and sulfur concentrations in the autumn at Great Smoky Mountain National Park have increased between 1985 and 1994. At Grand Canyon National Park in autumn, average sulfur concentrations have been increasing for the 25 percent most clear days.

Programs to Improve Visibility

EPA is developing a new regional haze program to address visibility impairment in national parks and wilderness areas that is caused by numerous sources located over broad regions. The program will build on recommendations received from the Grand Canyon Visibility Transport Commission as well as other committees. It will likely define a policy for achieving "reasonable progress" in improving visibility, as well as provide guidance on monitoring, modeling, and tracking emissions that cause haze. Because of common precursors and the regional nature of the ozone, PM, and regional haze problems, EPA is developing these implementation programs together in order to integrate future planning and control strategy efforts to the greatest extent possible.

Other air quality programs are expected to lead to emissions reductions that will improve visibility in certain regions of the country. The

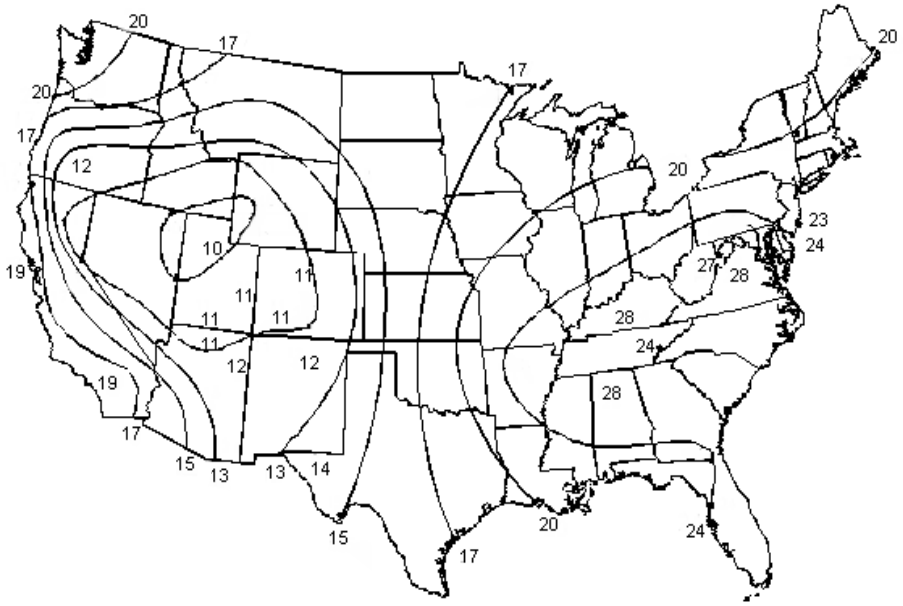

Figure 2-40. *Annual average visibility impairment in deciviews, 1992–1995 IMPROVE data.*

Figure 2-41. *Shenandoah National Park on clear and hazy days, and the effect of adding 10 ug/m^3 fine particles to each.*

Acid Rain program is designed to achieve significant reductions in sulfur oxide emissions, which is expected to reduce sulfate haze particularly in the Eastern United States. Better controls on sources of nitrogen oxides also can improve regional visibility conditions. EPA NAAQS, mobile source, and woodstove programs to reduce fuel combustion and soot emissions can benefit areas adversely impacted by visibility impairment due to sources of organic and elemental carbon.

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